Open Abdomen Treatment after Aortic Aneurysm Repair with Vacuum-assisted Wound Closure and Mesh-mediated Fascial Traction

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WHAT THIS PAPER ADDS

Most previous publications on treatment with open abdomen (OA) are on mixed patient cohorts. This article reports on a fairly large prospective cohort of aortic aneurysm patients who have been treated in a uniform way. The study shows that with the combination of negative topical pressure draining effectively the abdomen, and mesh-mediated traction pulling the fascia towards the midline, all surviving patients were possible to close without synthetic material. No patient was left with a giant hernia. The study also showed that prolonged OA treatment is a morbid procedure. If OA is necessary, the described method is effective.

Objectives: Open abdomen (OA) treatment is sometimes necessary after surgery for aortic aneurysm (AA), to prevent or treat abdominal compartment syndrome (ACS). A multicentre study evaluating vacuum-assisted wound closure (100–150 mmHg) and mesh-mediated fascial traction (VAWCM) was performed.

Methods: All patients treated with OA after AA repair (2006–2009) were prospectively registered at four centres; those treated <5 days were excluded. All surviving patients underwent a 1-year follow-up, including computed tomography (CT) examination.

Results: Among 1041 patients treated with open or endovascular repair of AA, 28 (2.9%) had OA treatment with VAWCM; another two had VAWCM after hybrid operations for thoraco-abdominal AA. Eighteen (60%) were operated on for rupture and 12 (40%) electively. Eight had suprarenal or thoraco-abdominal aneurysms. Eight (27%) died within 30 days, none due to OA-related complications. Four died before abdominal closure; primary delayed fascial closure was achieved in all survivors. One-year mortality was 50%. Ten (33%) had bowel ischaemia requiring bowel resection.

Late potential OA-related infectious complications occurred in five (17%), all of whom first developed intestinal ischaemia: entero-atmospheric fistulae (two), graft infections (two), aorto-enteric fistula (one). One year follow-up with clinical evaluation and CT showed no signs of graft infection. Incisional hernias occurred in 9 of 15 patients (60%); only three were symptomatic.

Conclusion: VAWCM provided high fascial closure rate after AA repair and long-term OA treatment. Infectious complications occur after intestinal ischaemia and prolonged OA treatment, and are often fatal. The poor prognosis among patients needing OA after AA surgery may be improved by using VAWCM, permitting earlier closure.

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OA treatment is applicable in multiple surgical settings. It may serve as a preventive and therapeutic measure in the septic abdomen, the tense abdomen after resuscitation, in damage control situations, or to treat the abdominal compartment syndrome (ACS).[1–4]

Management of the OA is a clinical challenge. Several techniques were developed, aiming to allow abdominal closure as soon as possible without compromising the patient's physiologic condition. In younger patients, predominantly suffering from trauma, fascial closure of the OA within 1 week is often possible.[5] In elderly patients undergoing treatment of OA after aortic aneurysm (AA) repair a longer duration is often required, and therefore a different technique is warranted in this subgroup of patients. The chosen OA technique must prevent adhesions between the intestines and the bowel, lateralisation of the

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bowel wall and contamination, thus permitting an early closure, which is the most important factor to avoid complications.[2] The longer the duration of OA treatment, the greater the risk becomes of developing serious complications such as graft infections, entero-atmospheric fistulae (EAFs) and other infections. We developed a novel technique, combining vacuum-assisted wound closure (VAWC) and mesh-mediated fascial traction (VAWCM).[6] To evaluate VAWCM a prospective multicentre study was performed on 111 patients treated for vascular or visceral pathologies, as well as trauma. The in-hospital mortality was 29.7%, and fascial closure rate was 89% among survivors. No patient was left with a large planned ventral hernia. Eight patients (7.2%) developed EAF, seven of whom had been operated on for intestinal ischaemia. EAF was an independent risk factor for failure of abdominal closure and fatal outcome.[7] This study is a subgroup analysis of the patients treated for AA.

PATIENTS AND METHODS

A multicentre prospective study was performed including all consecutive patients treated with OA at four study centres (Falun, Gävle, Malmö and Uppsala) between April 2006 and August 2009. Criteria for exclusion were abdominal wall hernia before OA treatment, anticipated OA treatment lasting <5 days (patients treated with OA <5 days often received VAWC only, and not VAWCM) and non-midline incisions.[7] The study was approved by the ethics committee of Lund University and registered at http://www.clinicaltrials.gov (NCT00494793).

This study is a subgroup analysis of the patients treated with OA with VAWCM after operation for AA; the technique used in all patients is described below. All surviving patients underwent a 1-year follow-up examination with clinical assessment as well as with a computed tomography (CT) of the abdomen to detect late complications, in particular graft infections, EAFs and incisional hernias.

Definitions

Intra-abdominal pressure (IAP) was measured intermittently as urinary bladder pressure through an indwelling catheter by means of the Foley manometer technique[8] (Holtech Medical, Charlottenlund, Denmark), before and repeatedly after initiation of OA treatment. Urinary bladder pressure, when measured correctly, reflects IAP and is recommended by the World Society of the Abdominal Compartment Syndrome.[9] Intra-abdominal hypertension (IAH) and ACS were defined according to the World Society of the Abdominal Compartment Syndrome consensus definitions.[9] ACS is defined as IAP $\geq$ 20 mmHg and/or abdominal perfusion pressure APP $<$ 60 mmHg (APP $=$ MAP $-$ IAP),[9] measured at least twice, with newly developed organ dysfunction or failure. Indications for OA in this study were development of ACS, IAH $>$ 20 mmHg and/or an abdomen too tense to close. Incisional hernia was defined as any abdominal wall gap with or without bulge in the area of a postoperative scar perceptible or palpable by clinical examination or imaging (CT). Graft infection was defined according to Szilagyi.[10]

The Sequential Organ Failure Assessment (SOFA) score[11] was used as an estimate of organ failure. Individual organ score ranges from 0 to 4, and the maximum score is 24. IAP and SOFA score were evaluated immediately before and the morning after initiation of OA treatment. IAP was measured 1 and 3 h after the abdomen had been left open, and after each redressing. Classification of OA status[2] was performed at initiation of OA treatment, at redressings and at fascial closure or in the event of death before closure. The grading system is described in Table 1.

Vacuum-assisted wound closure and mesh-mediated fascial traction

The techniques of VAWC and VAWCM were described earlier.[6,7] Patients were initially treated with only VAWC, to avoid prolonging the laparotomy as part of the damage control surgery.[1] A polypropylene mesh was applied at the first redressing after 2–3 days. A 30 $\times$ 30-cm mesh (Prolene®; Ethicon, Johnson & Johnson, Somerville, NJ, USA) was divided in two halves and sutured to the fascial edges on each side with a running 0 polypropylene suture (Prolene®; Fig. 1). A VAWC system (V.A.C Abdominal Dressing System; KCI, San Antonio, TX, USA) was applied; the perforated polyethylene sheet with a central thin polyurethane sponge was placed intra-abdominally, covering the viscera, and tucked under the abdominal wall far out laterally on both sides (Fig. 2). The two mesh halves were then sutured in the midline with a running 0 polypropylene suture, ventral to the polyethylene sheet. The thick polyurethane sponge was placed on top of the polypropylene mesh, and the wound was covered with occlusive self-adhesive thin polyethylene sheets. A continuous topical negative pressure (TNP) of 100–150 mmHg was applied (Fig. 3).

The mesh was opened in the midline, the inner layer of the V.A.C. dressing changed and the mesh tightened by approximating the mesh towards the midline, under general anaesthesia every 2–3 days. Dressing changes without mesh tightening were sometimes performed, when a fluid overload resulted in a risk to develop a secondary ACS. Finally, the entire mesh was removed after cutting the

Table 1. Classification of the open abdomen (OA).[2]

Grade	Description
1A	Clean OA without adherence between bowel and abdominal wall or fixity (lateralisation of the abdominal wall)
1B	Contaminated OA without adherence/fixity
2A	Clean OA developing adherence/fixity
2B	Contaminated OA developing adherence/fixity
3	OA complicated by fistula formation
4	Frozen OA with adherent/fixed bowel, unable to close surgically, with or without fistula

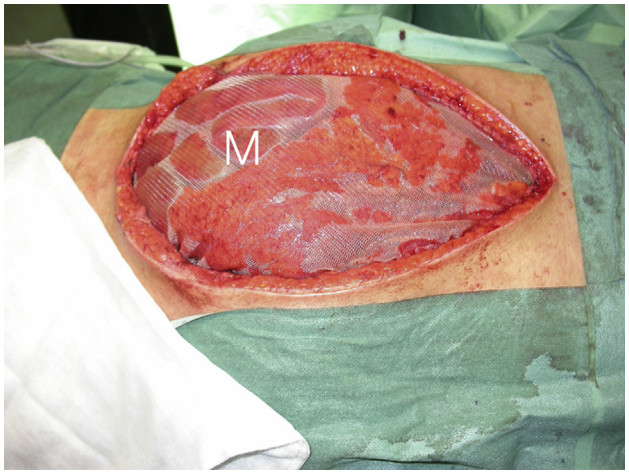

Figure 1. The two mesh halves (M) have been sutured to the fascial edges around the open abdomen.

running polypropylene suture in the fascial edges on each side. The fascia was then closed with a running 0 polydioxanone suture (PDS II, Ethicon, Johnson & Johnson, Somerville, NJ, USA), by means of a standardised suturing technique aiming at a suture length to wound length ratio of at least 4:1.[12] Successful delayed primary fascial closure was defined as complete closure of the whole length of the incised fascia.

Statistical analysis

Continuous variables were expressed as median (range), and group differences were analysed by means of the Mann–Whitney *U* or the Wilcoxon signed rank test. Dichotomous variables were analysed with the Fisher exact test. Statistical analysis was performed using IBM® SPSS® Statistics version 20.0 (SPSS, Chicago, IL, USA).

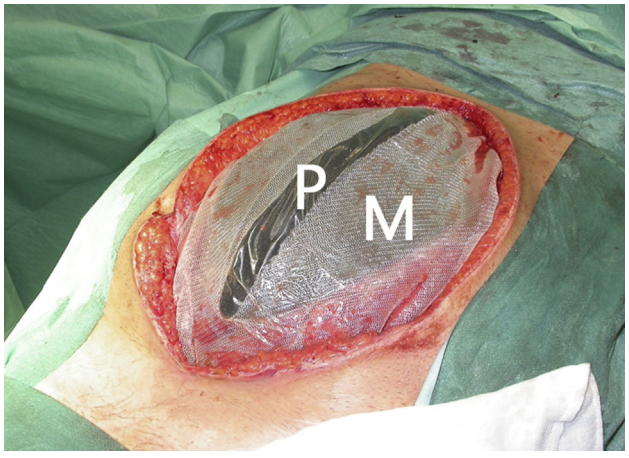

Figure 2. Each mesh half is retracted laterally and upwards to open the midline wound. The inner layer of the Abdominal VAC dressing (P) is applied to prevent adhesions between the intestines and the bowel wall, and to protect the bowel from contact with the mesh. The mesh halves (M) are then joined with a running 0 polypropylene suture.

Figure 3. The black foam is applied above the mesh. The dressing is covered with plastic sponge (S) and negative topical pressure is applied through the suction device (VAC). This patient had stomas placed far out laterally, a colonostomy to the left and an ileostomy to the right, to be able to achieve an effective sealing.

RESULTS

Thirty patients were treated with VAWCM after AA surgery, with open, endovascular or hybrid approach. Median age was 71 years (range 49–87 years): 26 (87%) were men. Eighteen patients (60%) were operated on for ruptured AA and 12 (40%) electively. Eight patients (27%) had suprarenal or thoraco-abdominal aneurysms. Pathology and operative techniques are described in Table 2. The frequencies of OA treatment, in the different subgroups of patients, are described in Table 3. The two patients who were treated with OA after hybrid procedures for thoraco-abdominal or suprarenal aneurysms were excluded from these calculations, since most of those patients were operated on with an extraperitoneal approach through a paramedian abdominal incision and thus were excluded from this study that excluded non-midline incisions.

The patients had a history of smoking (70%), hypertension (70%), cardiac disease (47%), pulmonary disease (20%), renal insufficiency (20%), diabetes, cerebrovascular disease and previous vascular surgery (13% each).

Table 2. Types of surgical procedure performed among 30 patients treated for open abdomen after aortic repair.

Surgical management	Ruptured aneurysm	Elective aneurysm
Open repair	14	3
OR of suprarenal aneurysm	1	4
EVAR	3	2
BEVAR	0	1
Hybrid approach (OR + TEVAR)	0	2
Total	18	12

OR, open repair; EVAR, endovascular aortic repair; BEVAR, branched EVAR; TEVAR, thoracic EVAR.

Table 3. Need for open abdomen treatment depending on pathology and type of procedure at the four study centres.

Pathology/procedure	No of procedures	No OA	OA%
Intact infrarenal AA, OR	303	3	0.9
Intact infrarenal AA, EVAR	455	2	0.4
Ruptured infrarenal AA, OR	115	14	2.5
Ruptured infrarenal AA, EVAR	86	3	3.4
Intact suprarenal AA[a], OR	11	4	36.4
Intact suprarenal AA[a], BEVAR/TEVAR	52	1	1.9
Ruptured suprarenal AA[a], OR	1	1	100
Ruptured suprarenal AA[a], BEVAR/TEVAR	18	0	0
Total[b]	1041	28	2.9

[a] Includes thoracic, thoracoabdominal, supra- and juxtarenal aortic aneurysms. AA, aortic aneurysm; OR, open repair; EVAR, endovascular aortic repair; BEVAR, branched EVAR; TEVAR, thoracic EVAR.

[b] Two patients with hybrid operations (OR and TEVAR) for suprarenal or thoraco-abdominal aneurysms were excluded from this analysis.

Indications for OA treatment

The indications for OA treatment were ACS in 13 patients (43%) and documented IAH in 4 patients (13%). In the remaining 13 patients it was considered impossible or unwise to close the abdomen, due to considerable tension of the abdominal wall at the end of the laparotomy, nine at primary and four at relaparotomy. Among the 13 patients with ACS nine were operated on for ruptured aneurysms and four electively. The abdomen was left open at primary or after relaparotomy in 9 (30%) and 21 (70%) patients, respectively.

Effect of initiation of OA treatment on IAP

The median IAP before OA treatment in 17 patients where we had a preoperative IAP measurement was 24 (14–43) mmHg, which decreased significantly to 12 (5–19) mmHg after initiation of OA ($p < 0.001$), 1–3 h after completion of the operation.

OA treatment and organ failure

The median SOFA score before OA treatment was 9.5 (1–16) and 10.3 (4–15) points 24 h after initiation of OA ($p = 0.34$). Three of 22 patients had a decrease in SOFA score with more than two points 24 h after initiation of OA. The median PaO_2/FiO_2 ratio was 23 (9–50) kPa before treatment, increasing to 30 (12–53) kPa after initiation of OA treatment ($p = 0.04$). Bilirubin increased from 16 to 19 ($p = 0.03$). Creatinine levels ($p = 0.07$) and platelet count ($p = 0.14$) remained unchanged.

VAWCM

The median fascial diastasis immediately after initiation of OA treatment was 21 (10–32) cm. The median duration of VAWC was 17 (4–87) days, with VAWCM for 14 (2–84) days. In the subgroup of 25 patients who survived until closure the median duration of VAWC was 17 (4–87) days with VAWCM for 15 (2–84) days. The median number of mesh-tightening procedures was 3.6 (0–8) in the group with final abdominal closure and 3.8 (0–8) in all patients. No patient developed a secondary ACS during or after the mesh-tightening procedure. The patient who had the longest treatment (87 days) had 24 redressings, but it was only possible to tighten the mesh 8 times. Continuous TNPs of 100 mmHg (4 patients), 125 mmHg (21 patients) and 150 mmHg (5 patients) were used.

Classification of OA

OA at the start of treatment was classified as grade 1A in 29 patients (97%) and 1B in 1 patient. At the end of OA treatment (before closure or at time of death) it was grade 1A in 26 patients (87%), grade 1B in 2 patients (7%), grade 3 and 4 patients in one each (3%). The most serious grades of OA recorded at any time in each patient were 1A in 24 patients (80%), 1B in 3 patients (10%), grade 3 in 2 patients (7%) and grade 4 in 1 patient (3%). The OA grade at the end, compared to at the start of OA treatment, was improved in 1 patient, unchanged in 25 patients (83.3%) and worsened in 4 patients (13.3%). Among the 25 patients with an unchanged grading, all patients had OA grade 1A at the start as well as at the end of treatment. Two had contamination after intestinal ischaemia and bowel resection, resulting in a more complex grade.

Fascial closure

Four patients died with an OA before fascial closure was possible. One patient had his abdomen closed after 87 days with a Permacol™ patch (Covidien, Mansfield, MA, USA), placed in the central part of the wound, but died on day 107. In the surviving 25 patients complete delayed primary fascial closure was achieved in all patients. No patient treated with VAWCM had a large incisional ventral hernia remaining for secondary granulation of the wound and later repair. The median suture to wound length ratio at closure, measured in 17 patients, was 5 (range 3.2–9.2).

Intensive care

The patients spent a median of 20 days (range 3–53) in the intensive care unit (ICU) and 49 days (8–220) in hospital. Twenty-nine patients (97%) had ventilator-assisted respiration at some stage of the treatment. Renal replacement therapy was needed in 17 (57%) and inotropic support in 29 (97%) patients.

Outcome and mortality

Intestinal ischaemia occurred in 10 patients (10/30, 33%), all of whom needed intestinal resection. Eight had

a colonostomy and two a bowel anastomosis. Potentially OA-related infectious complications occurred in five patients (17%). They were all treated for postoperative intestinal ischaemia, requiring relaparotomy, intestinal resection and then OA was commenced (Table 4). The two patients who developed EAF were treated with OA for a median of 22 days, compared to 13 days among the other patients. The patient who died after an early graft infection had stools sucked into the abdominal cavity from a colonostomy, a result of impaired healing.

The 30-day mortality was 27% (8 patients), the in-hospital mortality was 43% (13 patients) and the 1-year mortality was 50% (15 patients). In-hospital mortality for patients left with an OA after primary surgery was 2/9 (22%) compared to 11/21 (52%) after relaparotomy/decompression ($p = 0.23$). Patients decompressed for ACS had in-hospital mortality of 8/13 (62%) compared to 5/17 (29%) among those without ACS ($p = 0.023$). Patients operated on for ruptured AA had a 30-day mortality of 5/18 (28%) compared to 3/12 (25%) among the electively operated patients. One-year mortality in those groups were 8/18 (44%) and 8/12 (67%), respectively. Causes of death were multi-organ failure (four patients), myocardial infarction (three patients), cardiac failure (two patients), sepsis (two patients), acute respiratory distress syndrome (one patient), pneumonia (one patient), cardiac arrest (one patient) and unknown cause (one patient).

One-year follow-up

All 15 surviving patients were examined clinically and with CT 1 year after surgery. One patient had previously been treated conservatively for a graft infection and still had small gas bubbles near the graft on the CT 1 year after surgery but they had resolved after another 6 months. Another patient had signs of periaortic accumulation of fluid, which on a second CT had regressed. Both patients lacked clinical signs of infection and had normal CRP values, after >3 years of follow-up. One patient with endovascular treatment for an AEF showed no signs of ongoing infection.

Nine patients (9/15, 60%) had developed incisional midline hernias after a median follow-up of 16 months (range 12–25), but only three of them (20%) were symptomatic. Six patients had hernias above the umbilicus and three had hernias below the umbilicus. Among the three patients with symptomatic hernias, two underwent repair the third was not fit for surgery.

DISCUSSION

Treatment with OA may be life saving but is a morbid procedure, requiring repeated redressings in full anaesthesia and consuming considerable resources. The best is to avoid OA treatment all together, by an early proactive non-surgical management. When this was not possible VAWCM provided a high fascial closure rate, technique-related complications were few, but infectious complications occur after prolonged treatment and are often fatal. Given the facts that no patient developed a secondary ACS due to a too aggressive tightening and that there was an association between prolonged OA treatment and serious complications both in the larger study[9] and in this subgroup analysis, it is suspected that the patients' abdomens could have been closed more aggressively. With increasing experience, the surgeons tend to tighten the mesh with more force.

The 30-day mortality in this selected group of elderly patients with complex aortic disease, often suffering rupture and suprarenal aneurysm disease, requiring OA treatment, was 27%. In comparison, patients in general with a ruptured abdominal aortic aneurysm (AAA) in Sweden have a 30-day mortality of 36%.[13] The battle is not won at 30 days, however, in these severely diseased patients. After 1 year the mortality was higher compared to the same group, 50% versus 43%,[14] which may be attributed to the inclusion of patients treated with suprarenal AAs in the present study.

The frequency of OA treatment after AA surgery was low, <1% after elective repair, increasing to approximately 3% after rupture of an infrarenal AAA, and even further when suprarenal or thoraco-abdominal aneurysms were treated (Table 3). All the four hospitals practice measurement of IAH[8] and apply early proactive treatment of IAH with neuromuscular blockade, colloids and furosemide,[8,9] thus minimising the need for OA treatment.

The incidence of IAH > 20 mmHg after ruptured AAA is about 50% after OR and approximately 20% after EVAR on stable patients, and among those approximately half develop the ACS.[15] In a study from the Zürich group, in which virtually all patients were operated on with EVAR for rupture, 20% developed ACS.[16] In this study, in-hospital mortality for patients left with an OA after primary surgery was 22%, after secondary surgery 52%, and 62% among those decompressed for ACS, significantly higher. Does this imply that we should have been more proactive, opening the patients before ACS developed, or should we have left the abdomen open at the primary laparotomy? There is no simple answer to this question. The patient group is heterogeneous and subgroups have different risks of developing ACS, intestinal ischaemia and organ failure. This particular issue should ideally be addressed in a randomised controlled trial.

Table 4. Infectious complications after OA treatment.

Patient	Indication of aneurysm repair	Procedure	Graft related infection and time after OA	Treatment of graft related infection	One-year survival
1	AAA	EVAR	EAF day 15	Drainage with OA	No
2	TAAA	Hybrid	EAF day 30	Drainage with OA	No
3	rAAA	EVAR	Graft infection day 240	Percutaneous drainage + antibiotics	Yes
4	rAAA	EVAR	Graft infection day 25	Percutaneous drainage + antibiotics	No
5	rAAA	OR	AEF day 30	EVAR + antibiotics	Yes

The SOFA score has been used earlier to evaluate physiological changes following decompressive laparotomy. There was a clear decrease in IAP after decompression, but SOFA scores did not change within 24 h. Hence, the total SOFA score seems to be an imprecise scoring system to measure the apparent clinical beneficial effect of abdominal decompression. The utility of the SOFA score in this scenario has been questioned by others.[17] The results may also imply that the abdomen was opened too late in some patients. On the other hand, OA treatment is a morbid procedure. Patients who develop ACS are very sick, and untreated this condition is almost 100% lethal, which may explain that it takes several days to recuperate after such an event.

The most feared complications to OA treatment among vascular patients are infections, in particular EAFs and graft infections. In a review performed by Hensbroek et al.[18] EAFs were among the most consistently reported complications after all techniques of OA treatment. In the same study it was concluded that VAWC was associated with a low frequency of intestinal fistula (2.9%). In this study, all patients with infectious complications had previous intestinal ischaemia, and those who developed EAF had prolonged treatment with OA. Intestinal ischaemia is a major risk factor. Other studies have reported higher frequencies of EAF after OA treatment.[18] One study reported an association between the use of gastric or jejunal feeding tubes and EAF during OA treatment,[19] a practice avoided in this investigation.

One patient developed an aorto-enteric fistula (AEF) in the early postoperative period after open repair of a ruptured AAA. The patient suffered multiple complications, including bleeding and colonic ischaemia, requiring two separate relaparotomies and colonic resection, and was finally left with an OA. It is uncommon that AEF develops early postoperatively,[20] and it is unlikely that the OA treatment as such should have caused the AEF that was very distant from the VAWC device. It is more likely that there was an injury to the duodenum at one of the three laparotomies, combined with poor healing due to critical illness.

Endograft infection after EVAR seldom occurs within the early postoperative period, more typically 1—3 years after the endovascular operation.[21] It is unlikely that the contamination of the endovascular device should occur through the OA, and through the aortic wall, when the retroperitoneal space is closed. Both patients with stent graft infections in the present study suffered colonic ischaemia and had colonostomy. These stent-graft infections were more likely a result of haematogenic contamination.

The delayed primary fascial closure rate was 100% among survivors. In comparison, VAWC treatment alone without mesh-mediated traction resulted in a fascial closure rate of 70% among trauma patients with a mean age of 38 years.[5] The high frequency of primary fascial closure rate with the VAWCM technique has recently been reproduced in two independent investigations in Finland and Norway.[23,24] The risk of developing incisional hernia, however, was substantial (9/15), probably explained also by high age and catabolic state; the patients spent a mean of 20 days in the ICU. On the other hand, incisional hernia is a recognised late complication following AAA repair with an incidence of 32—37%[22] even without OA treatment. Furthermore, most of the identified hernias were asymptomatic and may not have been detected without CT, a great difference compared with the giant hernias that are the result of non-closure.

This study has several limitations, with the most important being the relatively small number of patients, and the fact that they were somewhat heterogeneous. Treating patients with OA after AA surgery is not a common procedure, however, and this is among the largest consecutive series published. The fact that all patients were treated according to a common protocol, and studied prospectively, are strengths. Whether the abdomen is too tense to close at the end of surgery is subjective, which unfortunately in a few cases leaves this indication for treatment with OA in a grey zone based upon experience and judgement. Furthermore, the follow-up was too short to detect late graft infections. The patients were well investigated, however: all were examined clinically and with CT. Laboratory examinations and FDG-PET/CT[18] were performed liberally when an infection was suspected.

CONCLUSION

VAWCM provided a high fascial closure rate after AA repair and long-term OA treatment. Infectious complications occurred after intestinal ischaemia and prolonged OA treatment, and were often fatal. Incisional, asymptomatic hernias were common. The poor prognosis among patients needing OA after AA surgery may be improved by using VAWCM, permitting earlier closure.

DISCLOSURES

MB and SA have lectured on open abdomen with salary from KCI, the supplier of the V.A.C Abdominal Dressing System.

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CONFLICT OF INTEREST

None declared.

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